

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)

3. DATES COVERED (From - To)

5a. CONTRACT NUMBER	
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5b. GRANT NUMBER	
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5c. PROGRAM ELEMENT NUMBER
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5d. PROJECT NUMBER	
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5e. TASK NUMBER	
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5f. WORK UNIT NUMBER

346204

8. PERFORMING ORGANIZATION
REPORT

10. SPONSOR/MONITOR'S ACRONYM(S)	
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11. SPONSOR/MONITOR'S
NUMBER(S)

Please see attached

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030116 039

16. SECURITY CLASSIFICATION OF:

17. LIMITATION OF ABSTRACT

18. NUMBER
OF PAGES

19a. NAME OF RESPONSIBLE PERSON

Leilani Richardson

a. REPORT

b. ABSTRACT

c. THIS PAGE

Unclassified

Unclassified

Unclassified

19b. TELEPHONE NUMBER
(include area code)
(661) 275-5015

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (TI) (STINFO)

04 Dec 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2000-231**
Hawkins, T., "Advanced Propellants"

**Visit by Swedish Diplomats to AFRL
(AFRL/Edwards, 05 Dec 2000)**

(Statement A)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

Comments: _____

Signature _____ Date _____

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.

Comments: _____

Signature _____ Date _____

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b) appropriateness of references, if applicable; and c.) format and completion of meeting clearance form if required

Comments: _____

Signature _____ Date _____

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/national critical technology, and f.) data rights and patentability

Comments: _____

APPROVED/APPROVED AS AMENDED/DISAPPROVED

PHILIP A. KESSEL Date
Technical Advisor
Propulsion Science and Advanced Concepts Division

ADVANCED PROPELLANTS

5 December 2000



Dr. Tom Hawkins
Sr Research Chemist
Air Force Research Laboratory



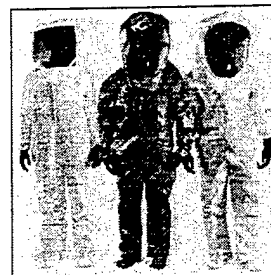
Problem



- Low Performance of SOTA Propellant
 - Low D^*I_{sp}
- Increased Operations Costs:
 - Carcinogenic Vapor (Respiratory Route)
 - Dermal Toxicity
 - Strong Reducing Agent
 - Flammable (LEL = 4.7%, UEL = 100%)
- On-Orbit Propulsion Systems Affected

<u>System</u>	<u>Mission</u>
FitSatCom	Military Comm
STARDUST	Deep Space Probe
INTELSAT	Commercial Comm
HEAO-B	X-Ray Astronomy

- Hundreds of Satellites Use Hydrazine for RCS & ACS

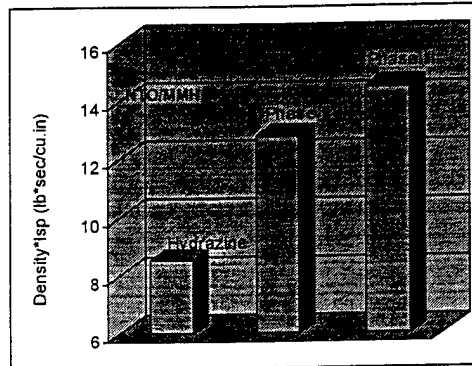




Monopropellant Performance Objectives



- Increase Density Isp of New Monopropellants for IHRPT Demonstration:
 - 50% by 2005
 - >70% by 2010
- New Monopropellants to Have Reduced Toxicity- Allowing Operations w/o SCAPE-suited Crews



USAF is Lead for IHRPT Monopropellant Development



Desirable Monopropellant Properties



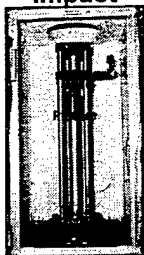
Characteristic	Objective
Density Isp [300 psi-vac; exp=50]	>70 % (Over SOTA)
Vapor Toxicity	Does Not Require SCBA
Carbon Content	No Solid Carbon Forms in Theoretical Exhaust
Melting Point	< 2°C
Detonability [NOL Card Gap]	Class 1.3; (Prefer 24 Cards Maximum (E_{50}))
Impact Sensitivity [Drop Weight]	20 kg-cm Minimum (E_{50})
Adiabatic Compression [U-Tube Test]	No Explosive Decomposition (Pressure Ratio of 35)
Thermal Stability	< 2% by wt. Decomposition for 48 hrs at 75 °C
Critical Diameter	No Propagation in Lines of < 0.75 inch Diameter



Ingredient/Propellant Testing



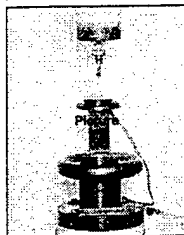
Impact



Friction



Electrostatic Discharge



Thermal

48 Hours

75 C

$\Delta T < 3C$
 $\Delta W < 2\%$



Adiabatic Compressibility

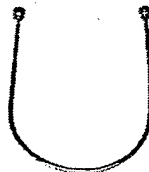



- Designed/Constructed Apparatus in FY00

- Propellant Sensitive to Rapid Compression




- Desired Result:
Insensitive to Rapid Compression





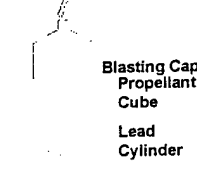
Propellant Testing

Shock to Detonation Tests



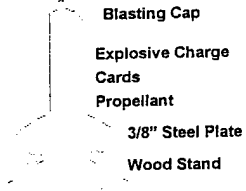
- All current solid rocket propellants are divided into two hazard classifications (1.1 or 1.3)
- Two tests are used to distinguish between classes 1.1 and 1.3.

Detonation Test




Blasting Cap
Propellant
Cube
Lead
Cylinder


Card Gap Test




Blasting Cap
Explosive Charge
Cards
Propellant
3/8" Steel Plate
Wood Stand




Dented
1/8" or
more is class 1.1



70 (0.7")
Cards
or more is
class 1.1



R&D Strategy For Reduced Toxicity Monopropellants



Technical Challenges

- High Toxicity and Vapor Pressure of N_2H_4 Creates High Costs
- Performance Limited by Low Energy Density (8.4 lb_s/in³)
 - Need 14.4 lb_s/in³ by 2010
- Highly Ionic Solutions Tend to Have High Melting Points

Approaches

- Use Ionic Compounds with Extremely Low Vapor Pressures and Structures of Reduced Toxicity versus Hydrazine
- Target Energetic Structures Which Confer High Isp
 - High N Content Cations
 - Anions (e.g., $C(NO_2)_3^-$, NO_3^- , $N(NO_2)_2^-$)
- Employ Miscible and Low Melt Point Components



PHASE II Monopropellant



ACCOMPLISHMENT

Synthesis/Delivery of 12 high-N salt compounds for additional toxicological screening at AFRL/HST

Evaluated monopropellant (Swedish Space Corp)

Produced liquid salt-type propellant for successful thruster test

SIGNIFICANCE

- Additional toxicity data on new propellants/compounds
- Supports development of QSAR for new propellant molecules' toxicity

- Has Phase II performance
- High solution miscibility temperature with hazardous solid residue

- Catalytic ignition verified
- Spurs hardware development
- Patent issues being worked



Monopropellant Properties



Properties	AFN1	AFN2	Hvdrazine
Density, g/cc	1.43	1.46	1.01
Viscosity, cp	8.6	23.1	0.97
Chamber Temp. (Theoretical), K	2070	2083	883
Carbon Content of Exhaust; (b)	none	none	none
Impact Sensitivity*, kg-cm (5 negatives)	>200	60	>200
Friction Sensitivity, N (5 negatives)	318	300	>371
NOL Card Gap (at 69 Cards)	negative	negative	negative
Thermal Stability, %wt loss/48hr, 75°C	<2.0	<2.0	(<0.1)
Melt Point, C	5 (c)	<-22	1

a: Theoretical, calculated with 300psi chamber pressure, exhaust to vacuum, 50/1 expansion

b: as soot or solid carbon (by theoretical computation)

c: by DSC, melt transition was broad, melt peak reported

*: For reference, n-propyl nitrate had an impact sensitivity of 8 kg-cm

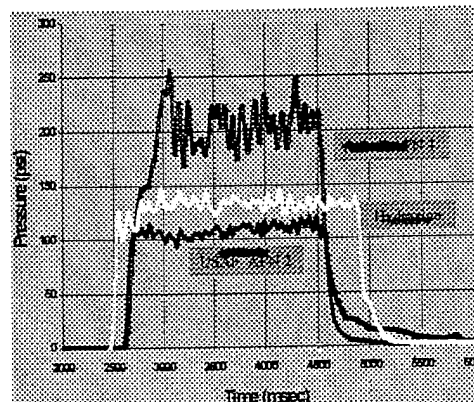
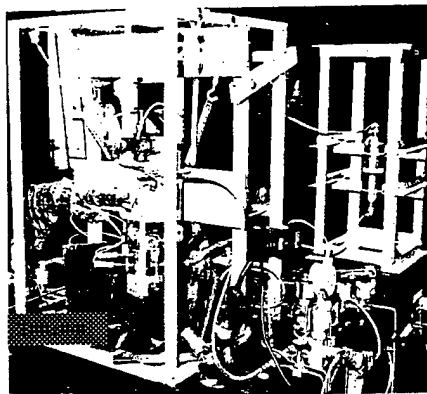
**AFN-Based Propellants Display Acceptable
Safety/Sensitivity Properties For Continued Development**



Monopropellant Thruster Testing



Monopropellant Thrust Stand



AFRL Fabricated Thruster and Initiated Testing



Catalyst Material Development



Contract Program Objectives

- SELECT CANDIDATE HIGH TEMPERATURE MATERIALS SUITABLE FOR CATALYTIC COMBUSTION OF AFRL MONOPROPELLANT
- MANUFACTURE AND SCREEN CATALYST/THERMAL BED SAMPLES
- EVALUATE PERFORMANCE OF DOWNSELECTED CATALYSTS IN THRUSTER FIRINGS WITH AFRL MONOPROPELLANT



Monolithic Catalyst Bed

AFRL Collaboration Activity in FY01

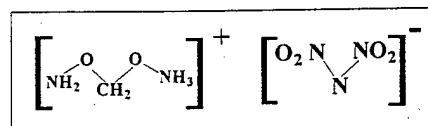
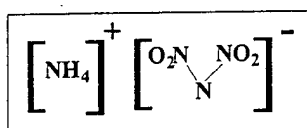
- EVALUATES CATALYST MATERIALS
- SUPPLIES PROPELLANT/COMPOUNDS FOR CATALYST EVALUATION



PHASE III MONOPROPELLANT Ingredient R&D



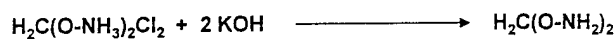
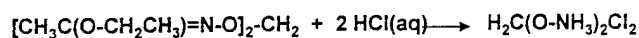
- Synthesizing/Evaluating dinitramide-based salts
- Many such salts (or salt-based monopropellants) exhibit 'challenging' safety properties
- Performed evaluations with ADN and MBO salts



Methylene bisoxamine $\text{H}_2\text{C}(-\text{ONH}_2)_2$



Dr. C.S. McDowell et.al. original work published as U.S.patents in 1973, in which the detailed synthesis of MBO selected salts



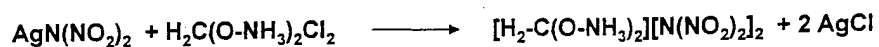


MBO bis(dinitramide) $[H_2-C(O-NH_3)_2][N(NO_2)_2]_2$

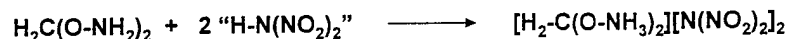


- Russians apparently synthesized through one or two routes:

- Metathesis with silver salts:



- Or, ion exchange:



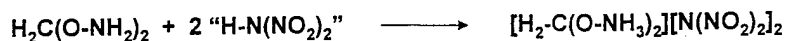
- Reported (1995) as a colorless oil with a melting point of 20° C.



Dinitramide Salts of MBO



USAF production via cation exchange / neutralization



Bis-dinitramide Salt:

Appearance: White crystals

M.P. 95° C

Impact: < 5 kg-cm (detonated with a light hammer blow)

DSC Exotherm: 103 °C

Mono-dinitramide Salt:

Appearance: White crystals

M.P. 96° C

Impact: 12 kg-cm (very friction sensitive)

DSC Exotherm: 119 °C



High Performance Monopropellants -Summary-



- **Continue work in monopropellant development & characterization**
 - **Promising, new approaches**
 - **Incorporating high energy density molecules**
 - **Encouraging initial propellant properties**
 - **Performance potential meets/exceeds bipropellant**
 - **Simpler, lighter propulsion system**
 - **Critical work remains**
 - **Stability, material compatibility, rheology**
 - **Propellant ignition , high temperature catalyst/materials**
 - **Teamed with industry**

Work with Industry for Successful Technology Demonstration